Chapter 12
Climate Change and Forest Fire in Eastern Himalaya: A Case Study of Sikkim and Darjeeling Himalayas of West Bengal

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Introduction

Forests are vital for the global carbon cycle, biodiversity conservation, climate change etc. Along with global organizations and civil societies, each country has a stern forest policy for the protection of existing forests as well as to increase forest coverage in their respective countries. Despite all these initiatives, global forest coverage has decreased by 3% in 16 years during the period of 1990–2015. In recent years, the rate of forest depletion has been at an alarming situation with 0.6% per year (FAO, 2015). Forest degradation is mainly due to forest fire, which are caused by both nature and anthropogenic-induced factors like climate change, rapid urbanization, infrastructural development, industries etc. It poses a great threat to all the lives on the earth, and many species are on the verge of extinction.

The area under forest in India is about 23.8% of the total geographical area. It covers almost 79 million hectares (FSI, 2011). Since ancient times, forests have been a pivotal to society and in everyday lives of people. It shapes the economy, livelihood, culture and religious practices. The most fragile ecosystem in India lies in the Himalayan region (Myers et al., 2000), which is also known as the yardstick of climate change. According to the Forest Report, 41% of the geographical area in the Indian Himalaya Region is under forest area, out of which 16.9% is under very dense forest cover, 45.4% under moderate forest and the remaining 37.7% under open forest category (FSI, 2011). The Himalayan region shows that a considerable forest area is under private (42%) followed by the area under community management (33%) and revenue department has only 25%. Pandit et al. (2007) reported on an alarming trend of deforestation in the Indian Himalaya and projected consequential extinctions of endemic *taxa* (species and subspecies) by 2100 across the broad range

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of taxonomic groups. The main degradation of forests in the region is due to rapid urbanization and forest fire both anthropogenic and natural factors. In India, annual forest fire ranges from 33% to 90% of forest areas in different states (Jaiswal et al. 2002). About 90% of the forest fires in India are caused by human intentionally or accidentally (NIDM, 2014). Thus, monitoring and management of forest fires is very important in India.

In this chapter, forest fire incidences have been studied in eastern Himalaya with climatic variabilities in the last 40 years (1981–2020) with forest fire data of 16 years (2000–2015). Eastern Himalaya in the Indian union includes Sikkim Himalaya, Darjeeling Himalaya and Arunachal Himalaya. There are three objectives in the study: first, to evaluate climatic variability in the study areas; second, to study spatio-temporal incidences of forest fire in the study area; and lastly, to analyse the impact of climate change on forest fire. The study also gives an account on the various forest types in the region, which are more likely to be affected.

Materials and Methods

The study is completely based on secondary data that were collected from different sources. To study climatic variabilities in the region, two stations from Sikkim and one station from Darjeeling had been selected. From Sikkim, one station from the urban centre, Gangtok, located at an altitude of 1650 m from MSL and another station at Lachung with an altitude of more than 3500 m from MSL, which is not influenced by any anthropogenic factors directly and covered mostly under snow, had been chosen for the study. It is necessary to take these two stations from Sikkim in order to check the impact of global climate change on the state climate and localized climate change due to urbanization. The climatic data of Gangtok was taken from IMD, Gangtok, for a period of 30 years from 1985 to 2015. Darjeeling climatic data were taken from an altitude of 1350 m from MSL. Both Darjeeling and Lachung climatic data were extracted from Merra-2, NASA, for a period of 40 years (1981–2020).

Forest fire incidence data were collected from satellite imageries, MODIS and Terra, from Bhuvan portal, ISRO. Forest fire data had been extracted from 2000 to 2015 for the period of 16 years. The incidences of forest fire had been plotted on a map with the help of ArcGIS version 10.2 to study the spatio-temporal aspect of forest fire incidences. The map from Google Earth imageries was also used to identify types of forests, which were affected by forest fire. LULC map extracted from the Bhuvan portal, ISRO was also incorporated to assess whether anthropogenic factors influence it or not. In the analysis, statistic techniques such as percentage and mean calculation were also used.

Study Area

The Eastern Himalaya comprises Sikkim, Darjeeling and Arunachal Pradesh of the Indian Union and Bhutan. In this study, Sikkim Himalaya and Darjeeling Himalaya had been taken (Fig. 12.1). Sikkim Himalaya lies in the state of Sikkim. Sikkim has four districts: East, West, North and South (Fig. 12.1). The altitude ranges from 8600 m to 300 m. It has a geographical area of 7096 sq. km, and an entire state comprising hilly terrain. The total population of the state is 610,557, and the literacy rate is 81.4% (Census, 2011). The total forest and tree cover of the state is 3377 sq. km, which is 47.59% of the geographical area. The area under protected forest constitutes 30.70% of the geographical area of the state. There are six types of forest in the state—Tropical moist Deciduous, Sub-Tropical Broad leave, Montane Wet Temperate, Himalayan Moist Temperate, Sub Alpine Forest and Moist Alpine Forest (Department of Forest, 2018).

Darjeeling Himalaya is situated between 26.31 and 27.13 degree latitude North and 87.59 and 88.53 degree longitude East. It includes the Darjeeling and Kalimpong districts of West Bengal. Darjeeling has four subdivisions: Darjeeling, Kurseong, Mirik and Silliguri. The altitude ranges from 2327 m on the north west to 60 m from MSL in the plain area on the south. The subdivision of Kalimpong under

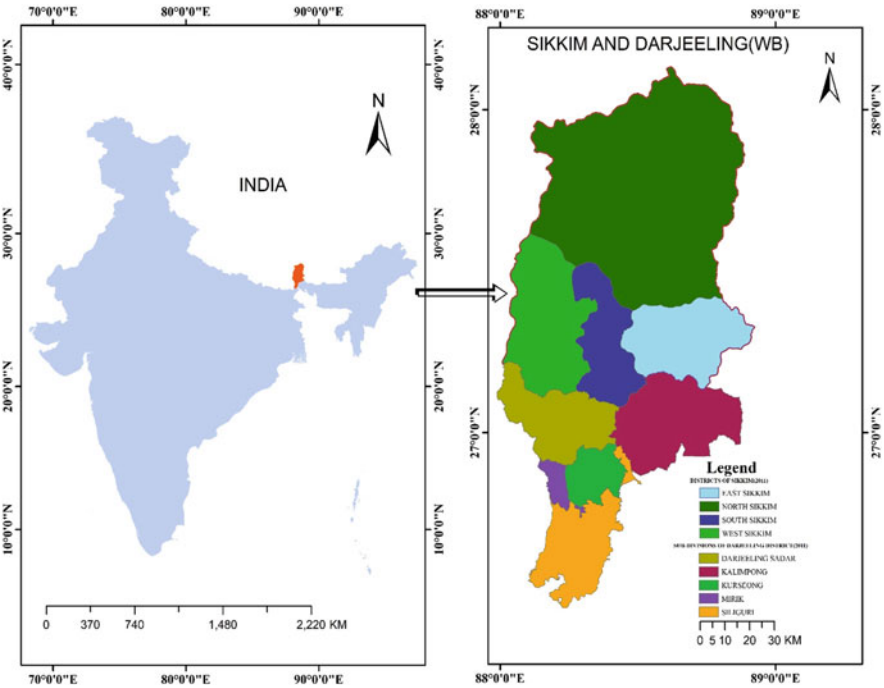


Fig. 12.1 Location map of Sikkim and Darjeeling and Kalimpong district, West Bengal

Darjeeling district became a full-fledged district on 14 February 2017 (Darjeeling Municipality, 2020).

Results and Discussion

Climatic Variability

(i) Sikkim Himalaya

Table 12.1 shows that the 1985–1995 mean decadal maximum and minimum temperatures at Gangtok were 22.37 °C and 12.20 °C, respectively. The average decadal amount of rainfall and number of rainy days were 3557.51 mm and 164.5 days, respectively. These figures had been slightly increased in the subsequent decadal period 1996–2005 where mean maximum and minimum temperatures were 22.41 °C and 13.30 °C, respectively. In this decade also observed more rainfall in terms of the amount and number of rainy days, i.e. 4359.29 mm and 183.2 days, respectively. The nature of temperature increase from the previous decade was mainly found in mean minimum temperature, i.e. +1.1 °C, whereas maximum temperature was raised by only +0.04 °C. The amount of rainfall increased from the previous decade was 602.64 mm, and number of rainy days also increased by 18.7 days in the decadal average. In the subsequent decadal period from 2006 to 2015, mean maximum and minimum temperatures were also observed more warming as 22.42 °C and 14.20 °C, respectively. The rate of increase in temperature from the previous decade is less when compared with the previous decade. The increase from the previous decade in mean minimum and maximum temperatures was +0.9 °C and + 0.01 °C, respectively. In terms of rainfall, both the number of rainy days and the amount were found lesser than the previous decadal period by − 7.2 days and − 602.64 mm, respectively. The decadal increase between 1985–1995

Table 12.1 Climatic variability at Gangtok, Sikkim (1985–2015)

Year	Rainy days	Rainfall (mm/yr)	T-min (°C)	T-max (°C)	T-mean (°C)
1985–1995 mean	164.5	3557.51	12.20	22.37	17.28
1996–2005 mean	183.2	4359.29	13.30	22.41	17.85
2006–2015 mean	170.0	3756.65	14.20	22.42	18.31
Decadal change (1985–1995 and 1996–2005)	+18.7	+801.78	+1.1	+0.04	+0.53
Decadal Change (1996–2005 and 2006–2015)	−7.2	−602.64	+0.9	+0.01	+0.46
Decadal Change(1985–1995 and 2006–2015)	+4.5	+199.14	+2	+0.05	+1.03
Grand mean	172.56	3891.15	13.23	22.40	17.81

Source: Indian Meteorological Department, Gangtok, Sikkim (2017)

Table 12.2 Climatic variability at Lachung, Sikkim (1981–2020)

Decadal year	Average Temp_Max (°C)	Average Temp_min (°C)	Total rainfall (mm)	Winter (mm)
1981–1990	13.2546	−2.83683	8775.51	207.85
1991–2000	13.60642	−2.91892	6708.09	221.51
2001–2010	13.71117	−2.35067	8710.63	183.92
2011–2020	13.26058	−2.34233	13245.49	269.9
Decadal from 1981–1990 to 1991–2000	+0.03564	+0.08209	−2067.42	+13.66
Decadal period from 1991–2000 to 2001–2010	+0.10475	−0.56825	+2002.54	−37.59
Decadal period from 2001–2010 to 2011–2020	−0.45059	−0.00834	+4534.37	+85.08
Decadal period 1981–1990 to 2001–2010	+0.45657	−0.4945	−64.88	−23.93
Decadal period 1981–1990 to 2011–2020	+0.00598	−0.4945	+4469.98	+62.03

Source: MERRA-2, NASA, 2022

and 2006–2015 in maximum and minimum temperature were +0.05 °C and + 2 °C, respectively, whereas for rainfall, more number of rainy days and more amount, i.e. +4.5 days and + 199.41 mm, respectively, in the later decade. The average temperature, average maximum and average minimum temperature between 1985 and 2015 were 17.81 °C, 22.40 °C and 19.12 °C, respectively. In 30 years, increase in temperature was profound at minimum and slightly at maximum. It shows clearly that climate change in the state in the last 30 years has caused a constant rise in temperature. This substantial increase in temperature is due to the rapid urbanization of Gangtok. But the amount of rainfall and the number of rainy days were observed to be highly fluctuating.

Table 12.2 shows the climatic variabilities from 1981 to 2020 at Lachung station located at an altitude of more than 3500 m from MSL where there is least direct human implication. For the decade of 1981–1990, the average maximum and minimum temperatures were 13.25 °C and − 2.83 °C, respectively. The total amount of precipitation received in this decade was 8775.51 mm. The total winter precipitation in the decade was 207.85 mm. In the following decade from 1991 to 2000, the average maximum and minimum temperatures were 13.60 °C and − 2.9 °C, respectively. The decadal average maximum and minimum temperatures were more than the previous decade by 0.05 °C in maximum and 0.082 °C in minimum. The total amount of precipitation in the decade was 6708.09 mm, which was much lower than the previous decade with an amount of 2067.42 mm. But the decadal total winter precipitation was 221.51 mm, which was more 13.66 mm than from the previous decade. In the decade of 2001–2010, the average maximum temperature was 13.7 °C, which was warmer than the previous decade by 0.10 °C and average minimum temperature was −2.35 °C which was colder from the previous decade by

0.56 °C. The total decadal precipitation was 8710.63 mm, which was much higher from the previous decade. But winter precipitation was found less than the previous decade. In the recent decade, i.e. 2011–2020, it was found colder than previous decade but experienced heavier rainfall than any decade in the last 40 years. During this decade, the average maximum temperature was 13.26 °C, which was colder than the previous decade by 0.45 °C and minimum average temperature was −2.34 °C, which was also colder by 0.008 °C from the previous decade. But in terms of precipitation, this decade received highest in 40 years, which was 13245.49 mm. It was around 4534.37 mm more than the previous decades. As well as in winter received precipitation about 269.9 mm, which was more 85.08 mm than the previous decade.

In the decadal comparison between 1981–1990 and 2001–2010, the average maximum temperature was higher by 0.45 °C but average minimum temperature was lower by 0.49 °C in 2001–2010. Summer experienced warmer and winter was more chilling than the previous decade. The total amount of precipitation received during 2001–2010 was lesser by 64.88 mm and winter precipitation also lesser by 23.93 mm. This shows that 2001–2010 was a warmer decade and more dryer too. Between 1981–1991 and 2011–2020, the maximum temperature was slightly increased by 0.0059 °C, whereas the minimum temperature declined by 0.49 °C in 2011–2020. This shows that global warming is also impacting Sikkim, which is warmer in summer and colder in winter. More melting of ice is likely to take place that accelerate ice recession.

From the study of climatic variabilities of two stations in Sikkim, i.e. Lachung and Gangtok, there is a clear indication of the impact of urbanization in Gangtok. At Lachung, the average maximum temperature in 40 years was increased slightly by 0.0059 °C and the minimum temperature was decreased by 0.49 °C which seems global influence. Whereas, in Gangtok, both maximum and minimum temperatures were found increasing, but increase in average minimum temperature was profound with 2 °C in three decades. Overall temperature at Gangtok increased by 1 °C in 30 years.

(ii) Darjeeling Himalaya

Table 12.3 shows the climatic variabilities at Darjeeling in the last 40 years from 1981 to 2020. In the decade of 1981–1990, the average maximum and minimum temperatures were 26.49 °C and 11.38 °C, respectively. The average amount of rainfall was 1297.72 mm, and total amount of rain during winter in the decade was 287.51 mm. In 1991–2000, the average maximum and minimum temperatures were 26.96 °C and 11.48 °C, respectively. The average rainfall was 992.752 mm, and total winter rainfall was 261 mm. It was found that 1991–2000 was warmer and drier than the previous decade. The increase in average maximum and minimum temperatures were 0.467 °C and 0.09858 °C, respectively from the previous decade. The amount of rainfall decreased by 304.9 mm on average. In winter, total amount of rain also found slightly decreased with 261.98 mm from previous decade. In the decade of 2001–2010, the average maximum and minimum temperature were 26.45 °C and 11.88 °C, respectively. The average decadal rainfall was 1313.043 mm, which was

Table 12.3 Climatic variability at Darjeeling, West Bengal (1981–2020)

Decadal year	Temp_Max (°C)	Temp_min (°C)	Rainfall (mm)	Winter
1981–1990	26.49892	11.38667	1297.726	287.51
1991–2000	26.965	11.48525	992.752	261.98
2001–2010	26.45942	11.88367	1313.043	231.49
2011–2020	26.24175	12.16125	1776.766	270.11
Decadal from 1981–1990 to 1991–2000	+0.467	+0.09858	−304.974	−25.53
Decadal period from 1991–2000 to 2001–2010	−0.506	+0.3984	+320.29	−30.49
Decadal period from 2001–2010 to 2011–2020	−0.218	+0.27758	+463.723	+38.62
Decadal period 1981–1990 to 2001–2010	−0.039	+0.497	+15.317	−56.02
Decadal period 1981–1990 to 2011–2020	−0.257	+0.7752	+479.034	−17.39

Source: MERRA-2, NASA, 2020

more rain than the previous decade by 320.29 mm, whereas winter rain decreased by 30.49 mm in total from the previous decade. This decade experienced a wetter and milder summer, whereas in the winter, it was warmer and drier than the previous decade. In 2011–2020, the average maximum and minimum temperatures were 26.24 °C and 12.16 °C, respectively. The decadal average and total rainfall in winter were 1776.766 mm and 270.11 mm, respectively. This decade had the lowest maximum average temperature, whereas minimum average temperature was recorded highest in the last 40 years. It means that the rise in temperature is profoundly marked in the minimum temperature. The minimum temperature has been rising continuously for the last 40 years, whereas the maximum temperature has been found to be very fluctuated. In the decadal comparison between 1981–1990, 2001–2010 and 2011–2020, it was found that 2001–2010 decade had a lower average maximum temperature of 0.039 °C and same in 2011–2020 with 0.257 °C when compared with 1981–1990. But average minimum temperature was recorded warmer in both subsequent decades than 1981–1990, i.e. 0.497 °C in 2001–2010 and 0.77 °C in 2011–2020. Same also recorded in rainfall: 15.317 mm more in 2001–2010 and 479 mm in 2011–2020 in decadal average rainfall, whereas winter rainfall were decreased by 56.02 mm in 2001–2010 and 17.39 mm in 2011–2020 from 1981 to 1990.

Forest Fire Incidences

(i) Sikkim Himalaya

The total number of forest fire incidences that occurred in the state for the last 16 years (2000–2015) was 120 (Table 12.4). Maximum forest fire incidences took place in 2006 with 41.50%, followed by 2014 with 14.15%. In these years, winter rain was very less. The maximum forest fire incidence took place in South district, i.e. 40 (33.32%), followed by East district with 30 (25.0%), North Sikkim with 26 (21.6%) and the least incidence in West district with 24 (20%). Forest fire incidences were confined in four months: January, February, March and April. Because in these months, most vegetation in sub-tropical deciduous forests become

Table 12.4 Forest fire incidence in Sikkim Himalaya (2000–2015)

Year	West district	South district	East district	North district	Total (%)
2000	–	–	–	–	Nil
2001	2 (Apr)	1 (Apr)	1 (Apr)	–	4 (3.3%)
2002	2 (Jan)	1 (May)	–		3 (2.5%)
2003	–	1 (Apr)	–	–	1 (0.8%)
2004	–	–	–	–	Nil
2005	2 (Mar)	1 (Mar), 1 (Dec)		2 (Dec)	6 (5%)
2006	2 (Jan), 5 (Mar)	2 (Mar), 2 (Apr)	14 (Jan)	19 (Jan)	44 (41.50%)
2007	–	–	–	–	Nil
2008	1 (Apr)	–	3 (Feb)	1 (Jan)	5 (4.7%)
2009	–	8 (Mar)	1 (Mar)	1 (Jan)	10 (9.43%)
2010	4 (Feb)	–	3 (Feb)	1 (Mar)	8 (7.5%)
2011	1 (Feb)	4 (Mar), 1 (Apr)	1 (Feb)	–	7 (6.6%)
2012	1 (Apr)	5 (Mar), 1 (Apr)	1 (Mar), 1 (Nov)	–	9 (8.4%)
2013	1 (Mar)	2 (Mar)	–	–	3 (2.8%)
2014	1 (Apr)	6 (Apr), 1 (Jan)	5 (Apr)	2 (Mar)	15 (14.15%)
2015	2 (Mar)	3 (Mar)	–	–	5 (4.7%)
Total	24 (20%)	40 (33.33%)	30 (25%)	26 (21.6%)	120
January	4 (16.6%)	1 (2.5%)	14 (46.6%)	21 (80.7%)	40 (33.3%)
February	5 (20.8%)	0	7 (23.3%)	0	12 (10%)
March	10 (41%)	25 (62.5%)	2 (6.6%)	3 (11.5)	40 (33.3%)
April	5 (20.8%)	12 (30%)	6 (20%)	0	23 (19.1)
May	0	1 (2.5%)	0	0	1 (0.8%)
November	0	0	1 (3.3%)	0	1 (0.8%)
December	0	1 (2.5%)	0	1 (3.84)	2 (1.6%)

Source: Bhuvan, NRSC, ISRO (2020)

dry and shed their dry leaves, as well as grasses on the ground also become dry. With this condition, small spark from natural or anthropogenic factors leads to extensive forest fire, which accentuated by a rainless winter. The highest occurrence of forest fire incidences took place in South district with 40 (33.3%). South district is drier than any other districts in the state. North district of Sikkim is the least populated district and mostly snow cover with evergreen alpine forest along with patches of pastural land. In 2006, 19 forest fire incidences took place in the district in January itself out of a total of 26 forest fire incidences in 16 years in a few concentrated area. It may be due to the minimum rainfall in winter in the state as well as rapid development in the areas. After that, North district had experienced the least forest fire incidence. In East district also, most of the forest fires happened in month of January (46.6%) and also took place in 2006. It may be caused by land-use changes due to rapid development and urbanization that affect local hydrology and micro-climatic conditions besides dry winter. In West district, mostly forest fire happens in the month of March (62.5%). In the state as a whole, 33.3% forest fire incidences took place in the month of March in the last 16 years (2000–2015). This shows that forest fire is related to the pre-monsoon's sudden rise in temperature associated with dry plants and grasses in sub-tropical forests. The same number of forest fire incidences took place in month of January that happened in 2006, 14 incidents in East district and 19 incidents in North district. February month experienced less comparatively with these four months, i.e. 10%. It may be due to a slight shower rain from the western disturbance. But a rare forest fire occurred in North district in the month of December in 2005. Most forest fires occurred up to the elevation of 1760 m from MSL, but few occurred exceptional above 3000 m where scrubs are found. Forest fires also took place in the months of May, December and November with negligible numbers. Spatially, most of the forest fires took place in open forests located near agricultural sites. In the higher altitudes, scrubs are more vulnerable (Fig. 12.3). The location of the forest fire mostly on lee ward sites (Fig. 12.4). It was also observed that forest fire in Sikkim mostly occurred near settlement, town, agriculture and along NH 31A, which give the figure of around 80% of the forest fire incidence. This shows that forest fire in the state is from anthropogenic causes and accentuated by climate condition. Most of forest fires (75%) have been occurred in and around sub-tropical deciduous forest. In 2004, 58.5 hectares of forest land was damaged by forest fire in which 80% occurred in Sal forest. In 2005, 225 hectares of forest land had been affected mostly in ground bushes and Sal forest (Department of State Disaster and Management, 2017). In 2014, the area affected by the forest fire was reported to be about 570 hectares in which ground bushes were affected, mostly Sal, teak, bamboo, etc. It was observed that exponential increased in effected areas.

(ii) Darjeeling Himalaya

Darjeeling Himalaya includes Darjeeling and Kalimpong districts of West Bengal. Four subdivisions of Darjeeling (Darjeeling, Kurseong, Mirik and Silliguri) and Kalimpong districts have been taken for the study of forest incidence in the last 16 years (2000–2015). Silliguri subdivision of Darjeeling is almost plain and least areas under forest land. The total forest fire incidences that took place in 16 years were 247 (Table 12.5). It is more than Sikkim because the forests in the southern part mostly belonged to tropical deciduous forest and are drier in the pre-monsoon season. Sikkim forest fire incidences are also located mostly along the boundary of Kalimpong. In Darjeeling Himalaya, Kalimpong district has more forest fire incidences than Darjeeling district, with an account of 52.63%. Most forest fires occur in areas that are below 1500 m MSL. In Kalimpong district, western part of it along the boundary of Darjeeling and southern part of the district along Duar region have the maximum concentration of forest fire (Fig. 12.2). In Darjeeling district, Darjeeling subdivision has the highest forest fire incidences with an account of 18.4%, followed by Mirik subdivision, i.e. 13.93% of the region. Kurseong subdivision has 8.9% least fire incidences among hilly regions because this subdivision receives more rain than other subdivisions. Silliguri subdivision has recorded least forest fire incidences, which is 6.55% because of the small area of the forest land and mostly land under settlement and agriculture. In Darjeeling subdivision, maximum forest fire took place in the eastern and southern parts, whereas middle and northern parts have less because of the high altitude above 1700 m from MSL. The west part of the subdivision also experienced more forest fire where it was located on the rain shadow. Mirik subdivision is the smallest subdivision but has extensive forest fire because of its location on rain shadow. Darjeeling and Kalimpong districts do not have areas above 3400 m. Ninety percent of forest fire occurred below an elevation of 1760 m (Fig. 12.2). Most forest fires took place in forests located near agricultural sites (Fig. 12.3). The location of the forest fire mostly on lee ward site (Fig. 12.4).

It was observed that forest fire incidences occurred in the region for eight months: January, February, March, April, May, September, October and December. The maximum number of forests occurred in the month of March, which accounted for more than 55.8% followed by April with 20%. Among these eight months, the least forest fire occurred in the month of May because of pre-monsoon rain.

Conclusion

Forest fire incidences have been a local issue, but they are also influenced by global phenomena. Its become very complicated presently. The incidence of forest fire has been increasing in an unprecedented way in terms of frequency and extension. It is clear from the observation of temporal incidence of forest fire that pre-monsoon in which sudden rise of temperature and dryness in the region specially in tropical and subtropical deciduous are the main responsible factors by which most of the forest fire. The forest fire incidences took place in the months of March and April in Darjeeling Himalaya, whereas in Sikkim Himalaya mostly occurred in the month of January followed by March, which shows the relationship with winter rain and pre-monsoon temperature. Most of the forest fires in this region are also caused by anthropogenic factors. Forest fire affects the ground and Sal forest extensively. The area affected by forest fire in this region has increased exponentially, but the number

Table 12.5 Forest fire incidences in Darjeeling Himalaya (2000–2015)

Year	Darjeeling subdivision	Kurseong subdivision	Mirik subdivision	Silliguri subdivision	Kalimpong district	Total (%)
2000	–	–	–	–	–	Nil
2001	–	2 (Mar)	–	1 (Mar)	4 (Mar)	7 (2.47%)
2002	–	–	–	–	6 (Oct), 2 (Sep), 1 (Dec)	9 (3.6%)
2003	2 (Apr), 2 (May)	1 (Jan)	–	–	1 (Mar), 1 (Apr), 1 (Dec)	8 (3.23%)
2004	1 (Mar)	1 (Mar)	2 (Apr)	–	1 (Mar), 1 (Sep), 1 (Oct)	7 (2.83%)
2005	1 (Apr)	1 (Mar)	–	–	3 (Mar), 3 (Apr)	8 (3.6%)
2006	4 (Mar), 2 (Apr)	–	2 (Feb), 1 (Mar), 1 (Jan)	4 Mar	2 (Jan), 10 (Mar), 1 (Apr)	27 (10.9%)
2007	–	–	–	–	3 (Oct), 1 (Dec), 1 (Feb)	5 (2.02%)
2008	4 (Mar), 2 (Apr), 1 (Feb)	–	1 (Mar)	–	6 (Mar), 2 (Feb), 2 (Apr), 2 (Sep), 1 (Oct), 1 (Dec)	22 (8.9%)
2009	3 (Mar), 1 (Apr)	1 (Mar)	3 (Jan), 1 (Feb), 8 (Mar)	2 (Mar), 1 (Feb)	1 (Feb), 13 (Mar), 4 (Sep), 1 (Oct)	39 (15.78%)
2010	4 (Mar), 1 (Apr)	3 (Mar), 1 (Apr),	3 (Jan)	1 (Apr)	1 (Feb), 6 (Mar), 1 (Apr)	21 (8.5%)
2011	6 (Mar), 1 (Apr)	2 (Apr)	4 (Mar)	1 (Feb)	2 (Feb), 11 (Mar), 5 (Apr), 1 (SEP)	33 (13.36%)
2012	3 (Mar), 1 (Apr)	3 (Mar), 2 (Apr)	4 (Mar), 2 (Apr)	1 (Feb), 4 (Mar)	1 (Jan), 18 (Mar), 4 (Apr)	43 (17.4%)
2013	–	–	–	–	–	Nil
2014	6 (Apr)	5 (Apr)	2 (Apr)	1 (Apr)	4 (Apr)	18 (7.28%)
2015	–	–	–	–	–	–
Total	45 (18.4%)	22 (8.9%)	34 (13.93%)	16 (6.55%)	131 (52.63%)	247 (100%)
January	0	1 (4.5%)	7 (20.58)	0	3 (2.3%)	

(continued)

Table 12.5 (continued)

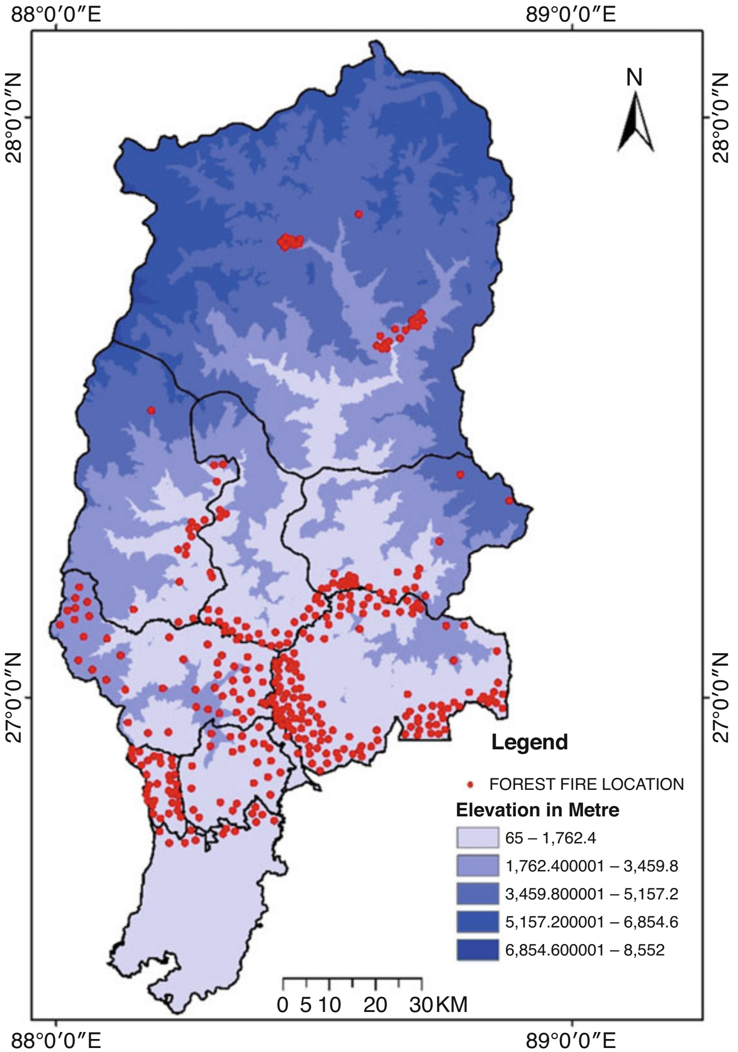
Year	Darjeeling subdivision	Kurseong subdivision	Mirik subdivision	Silliguri subdivision	Kalimpong district	Total (%)
						11 (4.45%)
February	1 (2.2%)	0	3 (8.8%)	3 (18.7%)	7 (5.38%)	14 (5.6%)
March	25 (55.5%)	11 (50%)	18 (52.9%)	11 (68.7%)	73 (56.15%)	138 (55.87%)
April	17 (37.7%)	10 (45.45%)	6 (17.64%)	2 (12.5)	21 (16.15%)	56 (22.67)
May	2 (4.4)	0	0	0	0	2 (0.8)
September	0	0	0	0	10 (7.6%)	10 (4.0%)
October	0	0	0	0	12 (9.2%)	12 (4.8%)
December	0	0	0	0	4 (3.0%)	4 (1.6%)

Source: MERRA-2, NASA

of forest fire incidence is fluctuated. As a result, precious biodiversities are lossed irreparably. It also affects to surface run off and declining soil fertility in the region.

More forest fire incidences occur in Darjeeling Himalaya than in Sikkim Himalaya because of its lower elevation and exposure to more dry and sudden temperature rises in the pre-monsoon season, accentuated by anthropogenic activities as Darjeeling Himalaya is located in the southern part. In Darjeeling Himalaya, Kalimpong also experienced more forest fire compared with Darjeeling district as it lies in a lower area. It is also clear from climatic variability in the last 40 years (1981–2020) that the temperature in this region is becoming warmer. This trend of climate change, so-called global warming, is also influenced by localized urbanization.

Forest fire has been a constant threat to the ecosystem, biodiversity, resources, properties etc. It is high time to save forests from forest fire. Changes in the attitudes and actions of individuals, stakeholders including the private sectors, and governments are instrumental in mitigating initiative programme for forest fire.



Source: ASTER DEM, ISRO 2015

Fig. 12.2 Forest fire with elevation in Sikkim and Darjeeling Himalaya (2000–2015). (Source: ASTER DEM, ISRO 2015)

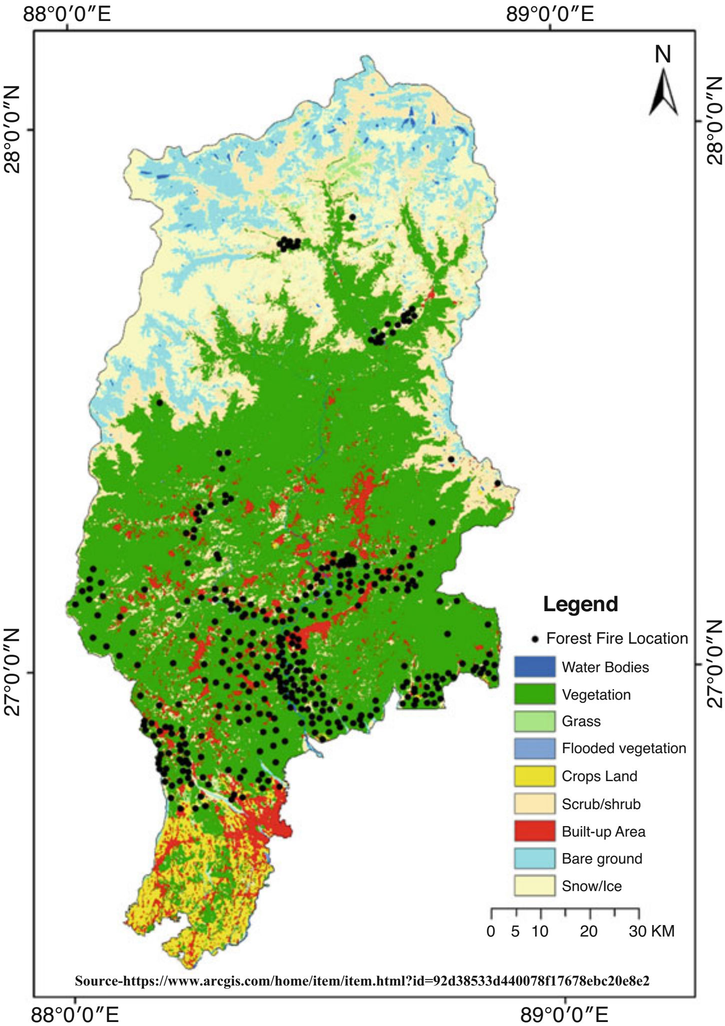
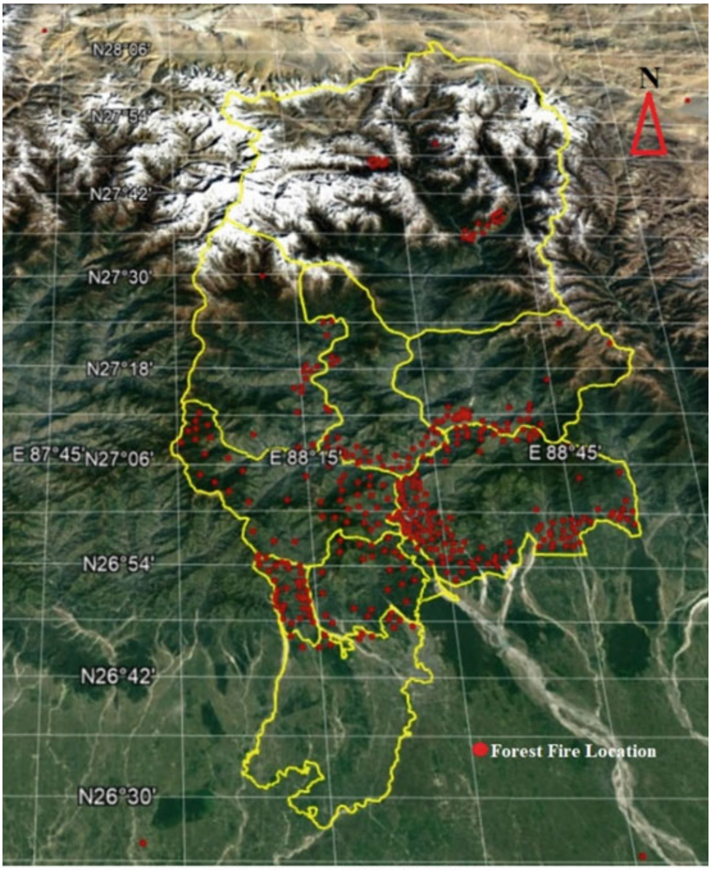


Fig. 12.3 Forest fire and different land use land covers of Sikkim and Darjeeling Himalaya (2000–2015)



Source: Google Earth and ISRO, 2015

Fig. 12.4 Forest fire in Sikkim and Darjeeling Himalaya. (Source: Google Earth and ISRO, 2015)

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